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ISOPOD

**Presumptive stridulatory organs in *Paranthura cf. japonica*
Richardson, 1909 (Isopoda: Cymothoidea: Paranthuridae)**

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ABSTRACT

Morphological diversity of sound-producing structures has not been well investigated among members of superorder Peracarida. Presumptive stridulatory sound-producing organs have been reported in some amphipods and tanaidaceans, and sound production by these organs has been documented in two isopod species in Oniscidea and Sphaeromatidea. Here we

describe three presumptive stridulatory organs in the paranthurid isopod *Paranthura* cf. *japonica* Richardson, 1909, the first case known in Cymothoidea. One type, consisting of a scale-bearing knob on the posterolateral corner of a pereonite and the scale-bearing anterolateral corner of the succeeding pereonite, was found between two pairs of pereonites (1, 2 and 2, 3). A second type involves a serrated structure in the sub-posterolateral region of pereonites 1 and 2, with the sharp anterolateral margins of pereonites 2 and 3 appearing to provide corresponding plectra. The third type involves an extension bearing a pair of serrated structures on the posteroventral margin of pereonites 1 and 2; the anterior-ventrolateral edges of pereonites 2 and 3 appear to provide corresponding plectra. All three organs occurred in both sexes of *P. cf. japonica*. Our discovery of novel, presumptive stridulatory organs in an intertidal isopod indicates that much remains to be learned about the biology of even common peracarid species.

Key Words: acoustics, Crustacea, functional morphology, Japan, Malacostraca, Peracarida, sound production

Many crustaceans produce sounds, which function in activities such as courtship, deterring predators, and stunning or killing prey (Versluis *et al.*, 2000; Patek, 2001; Boon *et al.*, 2009).

Various sound-producing mechanisms are known, including stridulation, snapping,

stick-and-slip, muscle contraction, and rapping (Dumortier, 1963; Versluis *et al.*, 2000; Patek, 2001; Henninger & Watson, 2005; Kido & Wada, 2020). Stridulation, in which a sound pulse is produced by two hard parts rubbing together, is the most common mechanism in Crustacea.

Sound production in the superorder Peracarida has not been well investigated.

Several amphipods and tanaidaceans bear presumptive stridulating organs on appendages and/or pleonites (e.g., Stephensen, 1938; Menzies, 1953; Ariyama, 2009; Lowry & Springthorpe, 2009; Kakui *et al.*, 2010; Kakui & Shimada, 2017; Kakui & Fujita, 2020).

Longo *et al.* (2021) reported that males of one amphipod species can produce sound by the snapping of a second gnathopod. In Isopoda, Oniscidea and Sphaeromatidea include members bearing stridulatory organs on pereopods and/or pereonites, which have been shown to function in producing sound (Caruso & Costa, 1976; Nakamachi *et al.*, 2015; Cividini *et al.*, 2020). Nakamachi *et al.* (2015) found that males, but not females, of the marine sphaeromatid *Cymodoce japonica* Richardson, 1906 produce sounds by stridulation and concluded that these sounds may be agonistic warning signals. Both sexes of the terrestrial oniscid *Armadillo officinalis* Duméril, 1816 produce sounds, which are thought to deter predators (Cividini *et al.*, 2020). We report herein the presumptive stridulatory organs in *Paranthura* isopods, the first case known in Cymothoidea.

Paranthura individuals were collected among algae in the intertidal zone at Oshoro, Hokkaido island, Japan (43°12'33.5"N 140°51'34.3"E) on 20 October 2020. All specimens

were fixed and preserved in 70–99% ethanol; one living male was photographed before fixation. The morphology of our specimens was consistent with the original description of *Paranthura japonica* described from the Hokkaido island by Richardson (1909) and the redescription of the species based on the holotype specimen by Nunomura (1975). The type locality of the species is “Mororan” (= Muroran) (Richardson, 1909) which faces the Pacific Ocean, not the Sea of Japan which Oshoro faces, leaving the possibility that our specimens represent a cryptic species of *P. japonica*. We thus refer to them herein as *Paranthura* cf. *japonica* Richardson, 1909. All individuals were sexed by checking for the presence or absence of an appendix masculina (a male trait; Wilson, 1991, fig. 13.2B) on pleopod 2. Three males and four females were observed with a stereomicroscope (SMZ1500; Nikon, Tokyo, Japan), and one male and two females were observed with a scanning electron microscope (SEM) (S-3000N; Hitachi, Tokyo, Japan). The methods used for dissection and scanning electron microscopy were as described by Kakui & Angsupanich (2012). All material studied has been deposited in the Invertebrate Collection of the Hokkaido University Museum (ICHUM), Sapporo, Japan, under catalog numbers ICHUM-6166–6175.

We found one type of presumptive stridulatory organ associated with three pereonites in both sexes (Fig. 1). Each organ comprises a scale-bearing knob (Fig. 1B, E–G, J, K) at the posterolateral corner of a pereonite and the scale-bearing anterolateral corner of the succeeding pereonite (Fig. 1E, F, J, K). The organs involve two pairs of pereonites: 1 and 2

(Fig. 1B–F) and 2 and 3 (Fig. 1G–K). In addition, each of pereonites 1 and 2 bears a sub-posterolateral serrated structure (Fig. 1E, J) that is in position to be rubbed against the sharp anterolateral margin on pereonites 2 and 3, possibly comprising another stridulatory organ.

<Fig. 1>

In both sexes, the posteroventral margin of pereonites 1 and 2 has a posterior extension bearing a pair of serrated structures (Fig. 2A–E). These extensions are exposed when the body is in a straight position (Fig. 2A) and inserted under the folded anterior articular membrane of pereonite 2 or 3 when the body is bent ventrally (Fig. 2B, E). Hard structures evident near the extensions are the anterior-ventrolateral edges of pereonites 2 and 3. The joints between pereonites 1, 2 and pereonites 2, 3 are unusually narrow (Figs. 1G, 2G), which may allow a wide range of movement dorsoventrally and laterally of pereonites 1 and 2 (Fig. 2F). Movement of pereonites 1 or 2 laterally and then ventrally may expose the serrated extensions and rub them against the anterior-ventrolateral edges of the pereonites; these may thus comprise another type of stridulatory organ.

In summary, we found three types of presumptive stridulatory organs involving pereonites 1–3 in both sexes of *P. cf. japonica*; the three types differ in form and location from stridulatory organs reported in other isopods. The stridulatory organs of oniscids comprise serial ridges on pereopods 4 and 5, and scales on the inner surface of the epimera of

pereonites 5–7 (Caruso & Costa, 1976). The stridulatory organs of sphaeromatids comprise serrated structures on the inner surface of pereonites 1–7, but corresponding plectra have not been detected (Nakamachi *et al.*, 2015). While we did not study living individuals and thus could not confirm that the organs we found in *P. cf. japonica* actually function to produce sound, they resemble in morphology the stridulatory organs in other arthropods, and a sound-producing function is the most likely interpretation. *Paranthura cf. japonica* are aggressive predators found among seaweed and mussel beds offering many hiding places. In captivity, they attacked and ate the sympatric tanaidacean *Zeuxo ezoensis* Okamoto, Oya, & Kakui, 2020 (S. Shiraki, unpublished data). If they actually use sound intraspecific communications may be the most probable use of sound.

Peracarids comprise the most speciose superorder in Crustacea (Appeltans *et al.*, 2012) and play important roles in ecosystems. *Paranthura japonica*, for example, is an invasive alien species in Europe and has had a moderate potential impact on native ecosystems (Tsiamis *et al.*, 2020). Our discovery of novel, presumptive stridulatory organs in an intertidal isopod species indicates that much remains to be learned about the biology of even common peracarid species.

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Figure captions

Figure 1. Presumptive stridulatory organs in *Paranthura cf. japonica*: male, ICHUM-6166 (A); male, ICHUM-6167 (B–K). Dorsal view of a living individual (A). SEM images showing pereonites 1 and 2 (left pereopods detached) in dorsal, lateral, and dorsolateral views; the boxes in C and D indicate regions enlarged in E and F, respectively (B–D). SEM images of presumptive stridulatory organs on pereonites 1 and 2 (E, F). SEM images showing pereonites 2 and 3 (left pereopods detached) in dorsal, lateral, and dorsolateral views; the boxes in H and I indicate regions enlarged in J and K, respectively (G–I). SEM images of presumptive stridulatory organs on pereonites 2 and 3 (J, K). p1–3, pereonites 1–3. Arrows, positions of presumptive stridulatory organs; white arrowheads, scale-bearing knob on the posterolateral corner of pereonite; black arrowheads, serrated structure; double arrowheads, scale-bearing anterolateral corner of pereonite. Scale bars: A = 1 mm; B–D, G–I = 500 μm ; E, F, J, K = 100 μm .

Figure 2. Possible stridulatory organs in *Paranthura cf. japonica*: male, ICHUM-6166 (A); female, ICHUM-6168 (B–E); female, ICHUM-6169 (F, G). Ventral view of a living individual, with arrows indicating a posterior extension bearing a pair of serrated structures on pereonites 1 and 2 (A). SEM images of pereonites 1 and 2 (pereopods detached) in ventral and ventrolateral views; the box in B indicates the region enlarged in C (B, D). SEM image

showing the serrated extensions on pereonite 1 (**C**). SEM image showing pereonites 2 and 3 (pereopods detached) in ventral view (**E**). SEM images of pereonites 1–2 and 2–3, respectively, in dorsal view (**F**, **G**). p1–3, pereonites 1–3. White arrowheads, serrated extension; black arrowheads, anterior-ventrolateral edge on pereonites 2 and 3. Scale bars: A = 1 mm; B–G = 100 μm .



